VAPOR PRESSURE AND HUMIDITY DIAGRAM.

551.57

By ROBERT E. HORTON.

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For many of the practical and commercial uses of humidity observations, results giving dew-point temperatures to the nearest degree, and relative humidity within 1 or 2 per cent of the true value, are sufficiently accurate. The determination of the dew point and relative humidity by means of psychrometric tables from wet and dry bulb readings requires the use of two separate tables and involves separate operations. If only air temperature and relative humidity are given, then to determine vapor pressure and dew point some calculation is required in addition to the use of tables.

Various diagrams for the solution of problems involving humidity have been prepared, but in general such diagrams are necessarily large in order to provide sufficient accuracy, and, furthermore, separate diagrams are usually required for reduction of psychrometric readings for the determination of humidity and dew point.

In a recent paper,[1] L. S. Hall has described a simple graphical method by means of which many curves, empirical and otherwise, can be reduced to straight lines. This is accomplished by the use of a varying scale for one of the coordinates. Applying this method to the temperature scale of an ordinary curve of maximum vapor pressures, a rectilinear vapor pressure line is obtained. This is shown by the diagonal line designated "Vapor Pressure" on figure 1. Vapor pressures in inches are given by a uniform scale underneath this line and at the base of the diagram, and temperatures by a varying scale at the right of the diagonal line. An advantage of this method of plotting as compared with the reduction of such curves to straight lines by logarithmic or other scales is that the latter in this instance give decreasing temperature scale intervals as the vapor pressure increases, whereas the method here used gives an increasing temperature scale with increased vapor pressure, thus facilitating accurate reading of the results from the diagram.

Since, with the scale system here used, the maximum vapor pressure line is straight, it follows that the vapor pressure lines for various percentages of relative humidities are also straight lines. These are represented by the radial diagonal lines to the left of the vapor pressure scale. Thus far the diagram affords a basis for direct reading of maximum vapor pressure at a given temperature, of relative humidity for any given temperature, and absolute vapor pressure, or of actual vapor pressure, for any temperature and relative humidity. In order to provide a complete graphical solution of humidity problems, it is desirable to include on the diagram means for the determination of the dew point from wet-and-dry-bulb-thermometer readings. For a given air or dry-bulb temperature, the dew-point temperature decreases as the depression of the wet-bulb increases, or, in other words, as the reading of the wet-bulb thermometer decreases. To express these relations, a horizontal scale of wet-bulb readings has been placed at the base of the diagram, and curved guide lines drawn such that the dew-point temperature is found on the temperature scale at a point horizontally opposite the intersection of the guide line for a given dry-bulb reading with the vertical scale ordinate through the given wet-bulb reading. The following examples illustrates the use and accuracy of the diagram:

Given wet-bulb reading 54°, and air temperature or dry bulb 60°, to find the dew point, vapor pressure, and relative humidity for 30 inches barometric pressure. The dew point is given on the temperature scale at "*b*," opposite the intersection at "*a*" of the guide line for dry-bulb reading 60°, with the vertical line through wet-bulb reading 54°, or 49°. Extend this line horizontally to the left of its intersection with the temperature diagonal—the vapor pressure is given vertically underneath the point "*d*" at "*e*" on the vapor-pressure scale, or 0.34 inch, and the relative humidity is given vertically above the intersection point "*d*," at the intersection of this vertical line with the 60° horizontal temperature line at "*f*," or 66 per cent.

The operation is very simple, since the three required values are found from two intersections, and two of them are on the same vertical line. The operation of determining the depression of the wet-bulb which is necessary in the use of psychrometric tables is here avoided.

Given the air temperature and humidity to find the vapor pressure and dewpoint—for example, with air temperature 83°, and relative humidity 67 per cent. Enter at 83° on the temperature scale. Run horizontally to the left to the intersection of this line with the relative humidity at the point "*f*," vertically underneath at "*g*" read the temperature of the dewpoint 71° on the temperature scale, and read the vapor pressure 0.76 on the vapor-pressure scale at the bottom of the diagram.

Given the air temperature and dewpoint, to find relative humidity. With air temperature 43° and dewpoint 37° at the intersection "*k*" of the horizontal line, through 43° on the temperature scale with a vertical through "*j*," corresponding to dewpoint temperature 37° on the vertical scale, read the relative humidity 80 per cent on the diagonal at "*k*," and the vapor pressure 0.22 at "*m*," vertically underneath the vapor-pressure scale.

As illustrating the accuracy of the diagram, the problems listed in the subjoined table were solved for wet- and dry-bulb readings, as indicated in the column headings. The correct values as determined from the psychrometric tables are given in column 2 in each instance.

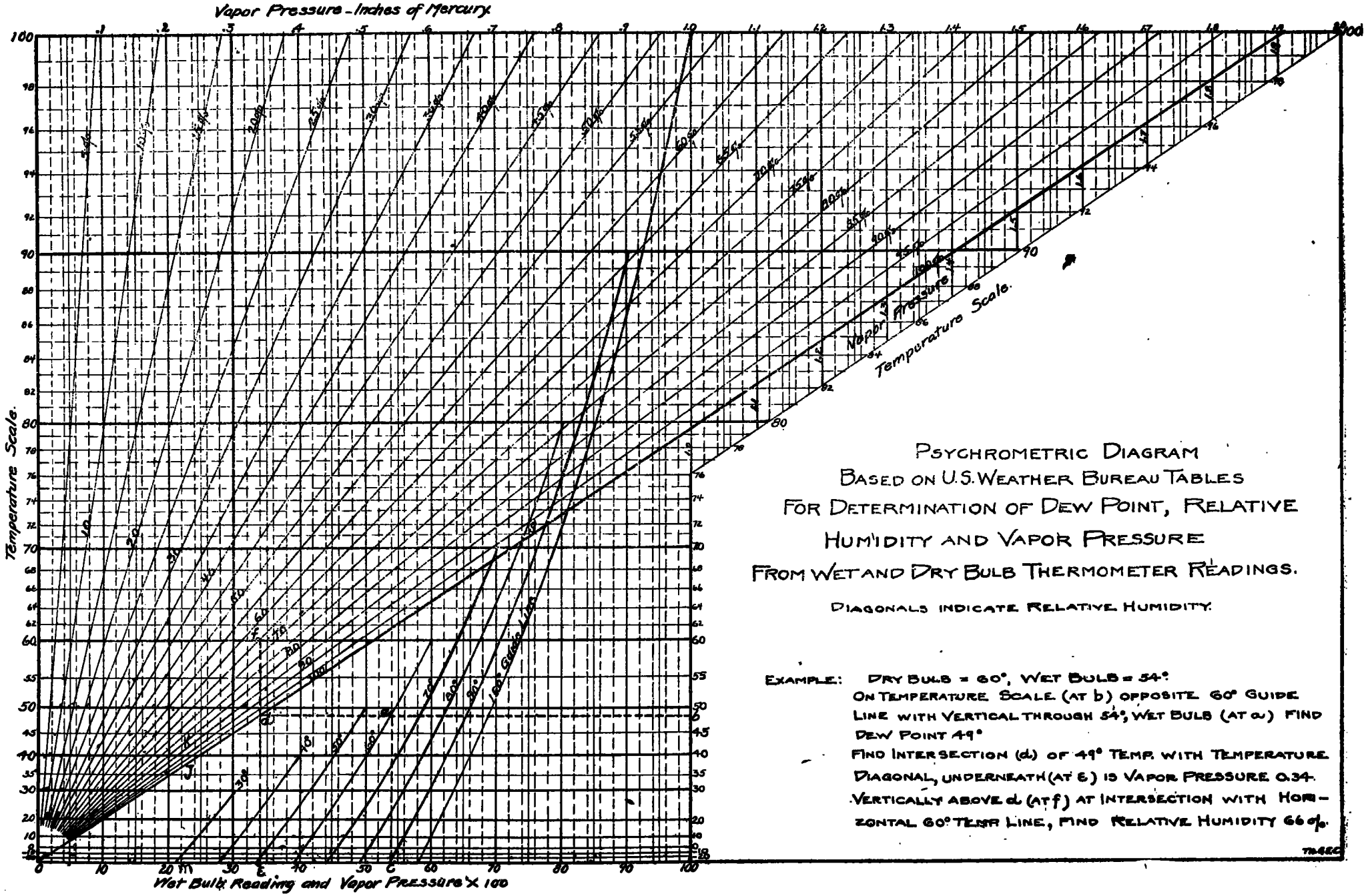
Comparison of results from diagram and tables.

	°F.		°F.		°F.	
Dry-bulb=	70		60		80	
Wet-bulb=	51		44		76	
	Diagram.	*Tables.*	*Diagram.*	*Tables.*	*Diagram.*	*Tables.*
Relative humidity	22	22	22	21	83	83
Vapor pressure	.160	.164	.115	.108	.840	.838
Dewpoint	29	30	22	21	74	74

Variation of dewpoint and relative humidity with barometric pressure for wet-bulb=54° and air temp. (Dry-bulb)=60°.

Barometer.	Dew-point.	Relative humidity.
Inches.	°F.	*Per cent.*
30	49	68
29	49	68
27	50	69
25	50	70
23	50	71

[1] Hall, L. S: The probable variation in yearly run-off as determined from a study of California streams. *A. S. C. E. Papers and Discussions*, 1920.



PSYCHROMETRIC DIAGRAM

BASED ON U.S. WEATHER BUREAU TABLES FOR DETERMINATION OF DEW POINT, RELATIVE HUMIDITY AND VAPOR PRESSURE FROM WET AND DRY BULB THERMOMETER READINGS.

DIAGONALS INDICATE RELATIVE HUMIDITY.

EXAMPLE: DRY BULB = 60°, WET BULB = 54°:
ON TEMPERATURE SCALE (AT b) OPPOSITE 60° GUIDE LINE WITH VERTICAL THROUGH 54°, WET BULB (AT a) FIND DEW POINT 49°
FIND INTERSECTION (d) OF 49° TEMP. WITH TEMPERATURE DIAGONAL, UNDERNEATH (AT e) IS VAPOR PRESSURE 0.34.
VERTICALLY ABOVE d (AT f) AT INTERSECTION WITH HORIZONTAL 60° TEMP LINE, FIND RELATIVE HUMIDITY 66 %.

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The diagram is prepared primarily for barometric pressure 30 inches. Results will be sufficiently accurate for most practical purposes whenever the barometric pressure is not less than 27 inches. The variation of dewpoint and relative humidity with barometric pressure is illustrated for the case of dry-bulb reading 60° and wet-bulb 54° in the subjoined table.

Most evaporation formulas, including that of the author, involve the maximum vapor pressure at the temperature of the evaporation surface, and the actual vapor pressure in the air, as factors. The diagram is especially adapted to the determination of these quantities, either from observational data where the dry-and-wet-bulb readings are given, or from published data where either the air temperature and relative humidity, or air temperature and dewpoint, are given.

A PSYCHROMETRIC CHART FOR DETERMINING THE DEWPOINT AND RELATIVE HUMIDITY.

551.571 (084.3)

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[1997 Vinewood Ave., Detroit, Mich., Feb. 19, 1921.]

Psychrometric observations are usually reduced by means of tables computed from some formula for the pressure of aqueous vapor in the air and from the known values of this pressure for saturated air. It is entirely feasible to perform this reduction graphically without the use of tables by means of a chart constructed according to the following principles:

(1) The addition of two quantities which can be represented with sufficient accuracy on a suitable scale can be effected graphically by laying a straight edge between two scales on which the two quantities are plotted and reading the value where the straight edge crosses a third scale, midway between the other two, in units one half as large as those used in plotting the quantities to be added, provided all three scales have their zero values on a straight line. This is clear from Fig. 1, in which a and b represent the quantities to be added and $a'+b'$ represents their half sum for all values of a and b.

(2) The subtraction of one quantity from another can be effected graphically by the same operation, provided the quantity to be subtracted is plotted in a direction opposite to that of the other two scales, as shown by Fig. 2, where evidently $a'-b'$ represents half the difference between a and b for all values of a and b.

(3) Multiplication or division can be performed graphically by substituting, for the numbers representing the quantities to be added or subtracted, their logarithms.

Fig. 3 illustrates the application of the foregoing principles to the graphical reduction of psychometric observations by a solution of the formula

$$e-e'-.00066\ B\ (t-t')\ (1+.00115\ t').$$

The factor B is incorporated in the solution as follows: If a, Fig. 3, represents a value of $.00066\times760\ (t-t')$, b the value 760 and b' the value of B, then $a'=B\ (t-t')=760B\ (t-t')/760$, since $a':b::a:b$, or $a'=ab'/b$.

The relative humidity is determined by measuring directly the difference between the values of log e', figure 3, corresponding to the temperature of the air and the temperature of saturation (dewpoint) respectively and subtracting this difference from the value of log 100.

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The chart when ready for use in reducing observations is simply lettered with the values of the psychrometric data corresponding to the values on the scales and with notes giving an explanation of the procedure to be followed

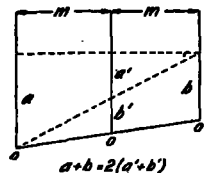

Fig. 1.

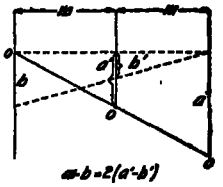

Fig. 2.

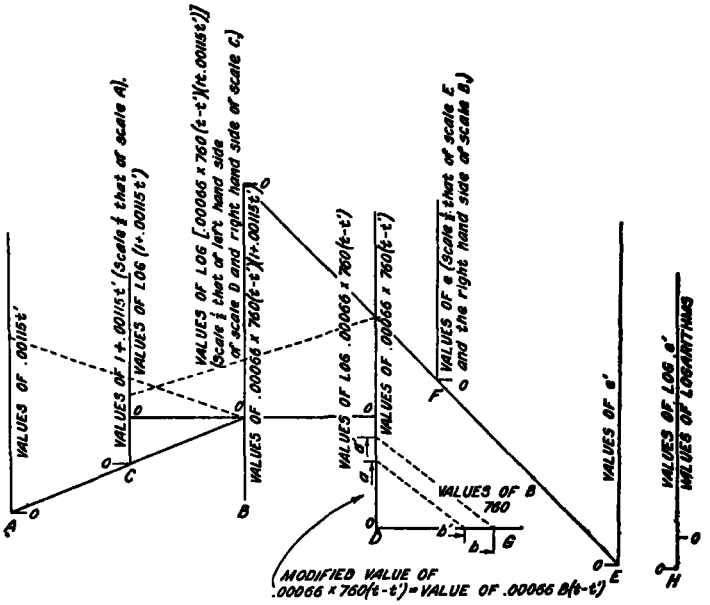

Fig. 3. SCHEME OF GRAPHICAL SOLUTION OF THE FORMULA $e=e'-.00066\ B(t-t')(1+.00115\ t')$ EMPLOYED IN CONSTRUCTING PSYCHROMETRIC CHART.